(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 344 882 B1

(12) # EUROPEAN PATENT SPECIFICATION

(45) Date of publication of patent specification: 27.12.95 Bulletin 95/52

(51) Int. Cl.[6]: G02B 26/10

(21) Application number: 89301850.7

(22) Date of filing: 24.02.89

(54) Low vibration resonant scanning unit for miniature optical display apparatus

(30) Priority: 31.05.88 US 200645

(43) Date of publication of application: 06.12.89 Bulletin 89/49

(45) Publication of the grant of the patent: 27.12.95 Bulletin 95/52

(84) Designated Contracting States: AT BE CH DE ES FR GB GR IT LI LU NL SE

(56) References cited:
EP-A- 0 301 801
GB-A- 2 142 203
US-A- 4 225 862
US-A- 4 453 170
US-A- 4 632 501

(73) Proprietor: REFLECTION TECHNOLOGY, INC.
240 Bear Hill Road
Waltham Massachusetts 02154 (US)

(72) Inventor: Wells, Benjamin A.
57 Hancock Street
Newton Massachusetts 02166 (US)

(74) Representative: Woodward, John Calvin et al
Venner Shipley & Co.
20 Little Britain
London EC1A 7DH (GB)

Jouve, 18, rue Saint-Denis, 75001 PARIS

Description

The present invention relates to a resonant vibrating light deflecting unit. Devices of this type are used to generate a raster scan image from a line of light-emitting devices.

There are many different types of display devices which can visually display information such as figures, numbers and video information. These devices include the ubiquitous cathode ray tube in which a raster is created by repetitively sweeping an electron beam in a rectangular pattern. The image is created by selectively modulating the beam to generate light and dark spots on the raster.

Another display device is an electromechanical scanning system in which a line of light-emitting devices is modulated with information to be displayed. The illuminated line is converted into a raster by means of an oscillating mirror thereby generating a virtual raster image. These latter devices have the advantage that a full "page" display can be created from a much smaller number of light-emitting devices than is necessary to generate a normal full page real image.

In operation, an enlarged, virtual image of the illuminated devices is reflected from a mirror as the mirror is being physically pivoted about a fixed axis by means of an electromagnetic motor. Although it is possible to directly drive the mirror to produce oscillations, in order to reduce the power necessary to drive the mirror, it is possible to use a resonant electromechanical oscillator to move the mirror. In such an oscillator, the mirror is mounted on a spring attached to a frame so that the mass of the mirror and the spring create a mechanical resonator. An electromagnetic motor oscillates the mirror mass at the resonant frequency of the spring/mirror system. In this manner, only a small amount of power is needed to produce a relatively large oscillation.

US-A-4632501 discloses such a resonant vibrating light deflecting unit, comprising a mounting base, a vibrating structure supporting a scanning mirror and resiliently mounted to the mounting base, and a driving motor means. Other light deflecting units of the same type are disclosed in US-A-4 453 170 and US-A-4 225 862.

A problem with the conventional mirror/spring oscillator system is that the rapid angular oscillation of the mirror requires a large spring force to accelerate and decelerate the mirror. The spring force is also applied to the base of the device and constitutes a "reaction force". When the base is rigidly secured to a relatively massive object, this force is not a serious concern. However, when it is impossible or undesirable to attach the display device to a massive object, as is the case for hand-held, eyeglass-mounted or "heads-up" displays, the force causes vibrations which are, at best, annoying and, in some cases, may cause the resulting image to be blurred or even unintelligible. In addition, the vibration can disrupt the function of an accompanying instrument, such as a microscope, that is sensitive to vibration. Further, even if the vibration is acceptable, the power required to oscillate the mirror increases when the vibration is transmitted to an external structure. This extra power means a larger motor is required to insure that the motor can drive the display with sufficient amplitude, in turn, resulting in increased battery drain for portable displays.

This problem is even more serious if the system design requires that the mirror pivot about a point near the end of the mirror as opposed to near the center of the mirror. Such a design is desirable in a hand-held display application because it permits use of smaller lenses and results in a more compact display.

Accordingly, it is an object of the present invention to provide a resonant scanning unit for an optical display device in which the net reaction force transferred to the mounting base is reduced.

It is a further object of the present invention to provide a resonant scanning unit which reduces vibration in a resonant-scanning optical display device.

It is yet another object of the present invention to provide a resonant scanning unit which allows the electromagnetic motor which drives the mirror to operate in an efficient manner.

It is yet another object of the present invention to provide a resonant scanner construction which uses a counter-balanced mass construction to reduce the net reaction force transmitted to the mounting base.

According to a first aspect of the present invention, there is provided a resonant vibrating light deflecting unit, wherein there is a second vibrating structure resiliently mounted to the mounting base, the driving motor means is arranged to oppositely vibrate the vibrating structures, and the masses of the vibrating structures and the resilience with which each is mounted to the mounting base are such that the reaction forces in the mounting base, caused by the operational vibrations of the vibrating structures, substantially cancel each other.

According to a second aspect of the present invention, there is provided a method of reducing vibrations of a resonant vibrating light deflecting unit having a mounting base, a first vibrating structure supporting a scanning mirror and resiliently mounted to the mounting base, a second vibrating structure resiliently mounted to the mounting base, and a driving motor means arranged to oppositely vibrate the vibrating structures, the method comprising the steps of: a) resiliently connecting the first vibrating structure to the base at a first point; b) resiliently connecting the second vibrating structure to the base at a second point, the second vibrating structure being selected so that the mechanical resonant frequency of the mirror and the first vibrating structure is sub-

stantially equal to the mechanical resonant frequency of the second vibrating structure; and d) positioning the first point relative to the second point so that the first reaction force substantially cancels the second reaction force at the base.

As both masses are attached to the same mounting base, it is possible to configure the arrangement so that reaction forces caused by the moving masses are cancelled at the base, thereby substantially reducing overall vibrations.

More specifically, the mirror support can consist of a "tuning-fork" configuration with the mirror mounted on one arm and a counterbalance mass mounted on the other arm. The driving motor may comprise a magnet and coil structure which drives one or more of the arms so that the arms move in opposite directions.

In one embodiment, the mirror is mounted to the base of the display device by crossed flexure springs. A counterbalance mass is also connected to the base of the video display device by a spring. The stiffness of both the mirror flexures and the counterbalance mass spring are selected so that the mirror and counterbalance mass have substantially the same resonant frequency.

In this embodiment, a voice-coil electromagnetic motor is used to drive the mirror and the counterbalance mass. The motor comprises a permanent magnet portion and associated magnetic return path mounted on one arm of the tuning fork configuration and a coil mounted on the other arm. When a properly controlled current is applied to the coil, the permanent magnet is alternately attracted and repulsed from the coil. In this fashion, a driving force is applied to both the mirror and the counterbalance mass causing each to oscillate at the frequency of the driving force.

The spring forces which accelerate and deaccelerate the mirror and counterbalance mass are also applied by the flexure springs to the base, and constitute "reaction forces". The geometry of the counterbalance mass and the counterbalance mass pivot point location are both selected so that the reaction force applied to the base by the counterbalance mass substantially cancels the reaction force applied to the base by the mirror.

In addition, the geometry of the electromagnetic motor is selected so that the drive forces applied to the mirror and counterbalance mass are substantially equal to the air resistance forces acting on the mirror and counterbalance mass, with the result that little or no net force is applied to the base due to drive forces.

Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic view of a typical prior art resonant electro mechanical scanner.

Figure 2 is a partial cross-sectional view of a resonant scanner constructed in accordance with the present invention.

Figure 3A is a schematic diagram of a miniature display using a scanning mirror which is pivoted near the mirror center.

Figure 3B is a schematic diagram of a miniature display using a scanning mirror which is pivoted near the mirror end.

Figure 4 is a perspective view of the resonant scanner shown in Figure 2.

Figure 5 is a perspective view of a preferred embodiment of a resonant scanner utilizing a drive motor with improve efficiency.

Figure 6 is a plan view of the preferred drive motor construction showing the mirror assembly overlaid by the counterbalance mass. Spring 42 which connects the mirror assembly to the base has been omitted for clarity.

Figure 7 is a cross-sectional view of the preferred drive motor embodiment taken along the line 6-6 shown in Figure 6.

Figure 8 is another cross-sectional view of the preferred drive motor embodiment taken along the line 7-7 shown in Figure 6.

Figure 9 is a longitudinal cross section of another embodiment using a sensor flag to sense position of the mirror 30.

Figure 10 is a partial exploded view of a portion of the embodiment shown in Figure 9 showing the voice coil with sensor flag, the counterbalance mass and the sensor assembly.

Figure 11 is an electrical schematic diagram of an illustrative drive circuit.

Figure 12 is a perspective view of a miniature optical display device utilizing an illustrative embodiment of the inventive scanner unit.

Figure 1 is a schematic diagram of a typical prior art resonant electromechanical scanner of the type shown in US-A-4632501. As this device is explained in detail in the latter patent, it will not be fully discussed herein. In the figure 1, the resonant scanner is used in a scanned image display device of the type described in the applicants published specification No. EP-A-0301801, constituting prior art within the meaning of Article 54(3) EPC. As the display device is described in detail in that application, which is hereby incorporated by reference, only a brief description of the operation will be given here.

In a scanned image type of display device, a row of light emitting devices 10 (which may illustratively be light-emitting diodes) is electrically excited to selectively emit light thereby generating an illuminated line. In Figure 1, the row of LEDs extends perpendicularly into the page.

The light from LED row 10 passes through an optical system schematically illustrated as lens 5, which creates an enlarged virtual image of the LED's. The image is reflected from mirror 30 to an observer's eye 15 as mirror 30 is repetitively oscillated in the direc-

tion arrow 16. Ny selectively illuminating the LEDs in row 10 as mirror 30 moves, a rectangular raster can be formed which van be observed by the viewer.

The mechanism which moves the mirror is generally termed as resonant scanner. It consists of a base 20 to which plane mirror 30 is attached by means of a flat spring 34 which extends perpendicularly into the page. Mirror 30 is oscillated by a drive motor consisting of two cylindrical permanent magnets 44 and 45 and two ring coils 46 and 47. In operation, one of coils 46 and 47, for example coil 47, is excited and the corresponding permanent magnet, 45, is either attracted into coil 47 or repulsed depending on the relative magnetic fields produced by coil 47 and magnet 45. The resulting force causes mirror 30 to pivot around the attachment point with spring 34 so that mirror 30 oscillates in the direction of arrow 16.

The remaining coil (coil 46 in the example) is used as a sensing coil to sense the motion of mirror 30. The electrical signals derived from the motion of magnet 44 relative to coil 46 are used by driving circuitry (not shown) to control the current provided to drive coil 47 in a conventional fashion and as described in the aforementioned Patent No. 4,632,501.

In practice, the mass and geometry of mirror 30 and the spring constant of spring 34 are chosen so that a resonant mass system is formed at the desired operating frequency. In this manner, a large excursion angle for mirror 30 is produced by a driving force which is much lower than would be required if the mirror were driven in a non-resonant fashion.

The problem with the mirror driving system shown in Figure 1 is that the spring forces which cause the mirror mass 30 to oscillate are also applied to base 20 and any supporting structures attached to base 20. Although mirror 30 is generally quite small, its motion is typically at a sufficiently high frequency that the forces are large in amplitude. These large amplitude forces are transmitted to base 20 causing it to vibrate in response.

Figure 2 shows a partial cross-sectional view of the mirror assembly of the present invention. The elements of Figure 2 which correspond to those of Figure 1 have been given the same numeral designations. In the Figure 2 structure, mirror 30 is part of a balanced assembly with two arms. One arm comprises mirror 30, mirror support 36 and driving coil 46. The other arm consists of weight 40 and permanent magnet 44. The mirror arm is attached to base mounting 21 by means of two flexure springs 32 and 34. Springs 32 and 34 are both flat springs which extend into the page. As will be discussed hereinafter, two springs are used in a crossed arrangement to constrain rotation of the mirror assembly to a single axis.

Mirror 30 is directly attached to a mirror support 36 (which may be comprised of a suitable plastic or other material) by means of adhesive or cement. One end of spring 32 is attached to mirror support 36 by means of a screw or rivet or other fastener. The other end of spring 32 is attached to base mounting 21 by means of another fastener. A second spring, 34, is also attached to mirror support 36 by fastener 37 and to base 21 by fasteners 39. Although not explicity shown, rectangular washers would generally be used with fasteners 39 in order to mechanically define the flexing point of the spring. The two flexure springs 32 and 34 act together so that mirror 30 and mirror support 36 effectively pivot around the point 48 at which springs 32 and 34 cross. Under influence of the driving motor, the mirror arm oscillates in the direction of arrow 16 around point 48.

Weight 40 is attached to the one end of spring 42 by means of fastener 43. Spring 42 is also a flat spring extending into the page. The other end of spring 42 is attached to base 21 by means of fastener 45. Weight 40 thus effectively pivots around an intermediate point located on spring 42 between attachment points 43 and 45.

Mirror 30 and weight 40 are driven by a voice-coil type electromagnetic motor consisting of permanent magnet 44 weight 40 and coil 46. Magnet 44 is rigidly secured to weight 40, while the coil 46 is rigidly secured to mirror support 36. Weight 40 is shaped with an overhanging portion 41 which acts to complete the magnetic flux return path and improve the efficiency of the motor. Circuitry is provided (not shown) to supply a sinusoidal current (or other periodic current, such as a square wave or current pulses) to the electrical coil 46. In accordance with one feature of the invention, the electrical connections between coil 46 and the driving circuitry are provided through springs 32 and 34 in order to avoid separate wires which are subject to fatigue from flexing.

The sinusoidal current in coil 46 generates a fluctuating magnet field which causes magnet 44 and coil 46 to be alternately attracted and repelled at the frequency of the current. The frequency of the sinusoidal driving current is chosen so that mirror 30 rotates through an arc segment at the resonant frequency of the spring/mass system consisting of mirror 30 and spring 32. Generally, the desired resonant frequency will depend upon the use of the scanner. In a scanned image display system as previously mentioned, the proper resonant frequency depends on the minimum display refresh rate to eliminate display "flicker". The resonant freqency can be selected in a conventional fashion by choosing the mass and geometry of mirror 30 and the spring constant of spring 32.

Advantageously, the use of the illustrative structure allows a light-weight drive coil to be placed on the mirror assembly rather than requiring a heavy magnet structure to be placed on the mirror assembly. This arrangement, in turn, allows the electromagnetic drive motor to be designed for efficient operation because the permanent magnet structure on the counterbalance arm can be large and heavy in order to pro-

duce a high magnetic field strength without contributing to the mass of the mirror arm.

When used in a scanned image display, the illustrative scanner has an additional benefit. Since the effective mirror pivot point 48 is located away from the center of mirror 30, a smaller mirror can be used to produce an optical system with a given "exit pupil". This advantage is illustrated in Figures 3A and 3B which show two display systems each utilizing an oscillating scanner mirror. Elements and locations in Figures 3A and 3B which are equivalent to those elements and locations shown in Figure 2 are given the same numeral designations.

Exit pupil 110 is defined as the area in which the user's eye 15 can be placed so as to see the entire image. In Figure 3A, a display system is constructed with a mirror pivoted near the center. As shown in the figure, the size of the exit pupil 110 is dependent on the arc through which the mirror swings and the geometry of the display. In Figure 3B, an exit pupil which has the same size as the exit pupil in Figure 3A can be achieved with a significantly smaller lens 5 and case size when the mirror is pivoted near one end according to one aspect of the present invention.

Figure 4 shows a partial perspective view of the illustrative embodiment of the resonant scanning unit with an accompanying housing shown in partial phantom detail. Figure 4 illustrates the connection of flexure springs 32, 34 and 42 between mirror 30 and weight 40 and the base mounting 21. In Figure 4, components which are equivalent to those shown in Figure 2 are given the same numeric designations.

Flexure spring 34 is illustratively a U-shaped spring made out of a single layer of flat spring material. Similarly, flexure spring 32 is a single layer flat spring which is mounted between the legs of spring 34 at a right angle to the plane of spring 32. This "crossed" spring design constrains movement of mirror mass 30 to essentially pure rotation whereas the single spring design common in conventional units is subject to undesirable twisting movements. Spring 42 is another U-shaped spring which fastens weight 40 to base 21.

The design of the mirror assembly and counterbalance mass in order to accomplish cancellation of the reaction forces can be carried out in a conventional manner. In particular, in accordance with conventional mechanical design theory, the reaction forces on a mass/spring system can be represented by a pair of force vectors which act at a conceptual "point of percussion". Although the actual moving part will have both mass and rotary moment of inertia these may be modeled as an equivalent point mass located at the point of percussion.

A secondary force vector passes through the point of percussion and the system pivot point and represents centrifugal force. A primary force vector passes through the point of percussion and is perpendicular to the secondary force vector and represents the force needed to translate and rotate the mass about the pivot point.

In operation, in the illustrative resonant scanner, the primary force vector has a relatively large sinusoidal magnitude which causes the mirror to accelerate back and forth (the magnitude of the force is greatest at the extreme ends of travel of the mirror). This force depends only upon the equivalent mass of the mirror assembly and the amplitude of mirror travel and, with proper pivot point placement and design, can be substantially cancelled by the reaction forces generated by the counterbalance mass. Specifically, the geometry of the mirror and counterbalance mass must be adjusted so that the primary force vectors are co-linear. In an illustrative embodiment constructed in accordance with the invention and operating at a scan frequency of 50 Hz., it has been found that this force is approximately 42 grams-force (gmf). It has been found that with a mirror mass of 3.36 grams, a counterbalance mass of 10.95 grams has produced effective cancellation of this force.

A much smaller drag force also acts upon the mirror assembly. This force is primarily a velocity-proportional force due to air resistance. In the previously mentioned illustrative embodiment constructed in accordance with the principles of the invention, the "Q" value for the mirror assembly alone is approximately 100 resulting in a drag force of about 0.4 gmf (the "Q" value is a measure of damping and has to do with the sharpness of the resonant peak). In order to make up for the energy lost due to the drag forces, voice coil motor 46 supplies a force to move mirror 30. If the drive force is a sine wave it can be made to substantially balance the previously-mentioned force resulting from drag.

Similarly, a drag force also acts on the counterbalance assembly. In the preferred embodiment described above, this latter force is approximately 0.2 gmf, corresponding to a "Q" of 200 for the counterbalance mass alone. The "Q" of the mirror assembly alone is lower because of its larger surface area. To minimize any extraneous forces resulting from imperfectly cancelled motor forces, in the illustrative embodiment, the motor torque exerted on the mirror and the counterbalance mass by the voice coil motor must be in the ratio of 0.4/0.2. The geometry of the illustrative embodiment has been designed to substantially accomplish this result.

Although a sinusoidal drive force applied in the correct ratio theoretically results in substantially zero net drive-related forces applied to the base, a non-sinusoidal drive force can also be used. If the drive force is periodic but not sinusoidal, a small net force will be applied to the base, but this force may be acceptable in view of simplifications possible in the motor drive circuitry.

Further, since the equivalent mass of the mirror

moves in a slight arc rather than in a straight line, there is also secondary force vector (mentioned earlier) caused by the transverse motion of the equivalent mass. This secondary force vector represents centrifugal force. The magnitude of this secondary force vector is substantially sinusoidal and has a frequency twice the frequency of the mirror motion. The double-frequency force will cause a slight vibration of the device base or, if the base is prevented from moving, the reaction force will be transferred to the supporting structure. A similar force acts on the counterbalance mass assembly. With the mirror and counterbalance configuration shown in the illustrative embodiment, the double-frequency forces for the mirror assembly and the counterbalance mass assembly are in the same direction and, consequently, do not cancel. However, as the extent of the transverse movement of the mirror and counterbalance masses is very small for example, in the illustrative embodiment approximately ± 42 um for the mirror and ± 5 um for the counterbalance mass, the vibration which is produced is acceptable. When incorporated in a display of total weight 42 gm, the resulting case vibration would be ± 7 um.

It is also possible to mount the scanner assembly in a compliant mount which can allow slight motion of the display case so that vibrations caused by unbalanced forces do not cause vibration of the structure to which the display is attached.

Figure 4 also shows the electrical connections of coil 46 through flexure springs 32 and 34. Since two separate flexure springs, 32 and 34, are used to support mirror 30 these springs may also be used in order to carry electrical current to coil 46 and, thus, eliminate the use of separate wires which may be subject to breakage due to repeated flexing. In particular, one electrical lead, 50, of coil 46 is attached to flexure spring 34 by means of fastener 37. Another electrical lead, 55, is attached to flexure spring 32 by means of fastener 35. Electrical connections to coil 46 can be completed by making appropriate electrical connections to the other ends of the flexure springs 32 and 34 at fasteners 33 and 39, respectively. Current is thus carried along the flexure springs directly to coil 46.

Figures 5-8 show an alternative embodiment of a resonant scanner unit that uses a preferred construction of the voice coil motor. This preferred construction increases motor efficiency by achieving higher magnetic field strength in the air gap. With a motor construction as shown in Figures 2 and 4, inefficiency results because the air gap between the inside diameter of toroidal coil 46 and magnet 44 must be sufficient to accommodate the varying arcs through which mirror 30 and weight 40 move. The relatively large tolerance which is required in order to prevent physical collisions results in high flux leakage and low field strength in the air gap, and, thus, in poor motor efficiency.

The motor design shown in Figures 5-8 improves motor efficiency by optimizing the magnetic circuit to reduce leakage flux. Parts of the assembly which remain the same as the embodiements shown in Figures 2 and 4 are designated with the same numerals. In particular, the toroidal-shaped coil 46 shown in Figure 4 is replaced by a rectangular coil 66 shown in Figures 5 and 6. Instead of a single cylindrical magnet 44 as shown in Figure 4, weight 40 has been modified to have an "E" shape with three fingers, 70, 72 and 74 shown in the cross-sectional view of Figure 7. Central finger 72 fits into the rectangular opening 73 in coil 66 as shown in Figures 7 and 8. The two side fingers 70 and 74 are provided with magnets 73 and 75 which lie on the outside of coil 66 as shown in Figures 7 and 8.

Also shown in Figure 5 is a slot 76 which is cut in weight 40. This slot, as will hereinafter be described, is used to accommodate a mechanical sensor that senses the position of mirror 30 and generates electrical signals which control the driving current to ensure that mirror 30 and weight 40 oscillate at the desired resonant frequency.

Figures 6-8 also shown an improved mechanism for attaching spring 42 to weight 40. As shown, spring 42 is clamped between two clamping members 45 and 47. Clamp members 45 and 47 have slots 51 (shown in Figure 6) which allow the members to be slid over fasteners 43. The ends of spring 42 which are fastened by fasteners 43 are not slotted, thus the distance between the wieght 40 and base 21 is mechanically fixed. However, clamping members 45 and 47 can be moved relative to weight 40, thus effectively changing the attachment point of spring 42 to weight 40. Thus, the effective spring length can be changed for the purposes of adjusting the resonant frequency without changing the basic geometry of the device.

Figure 9 is a partial cross-section of the resonant scanning unit of Figures 5-8 fitted with a position sensor mechanism. The main components of this mechanism are also depicted in the partial exploded view shown in Figure 10. The sensor mechanism consists of a "flag" 80 which is mounted on one end of rectangular coil unit 66. When the unit is assembled, flag 80 extends between the two arms of LED/photocell sensing unit 90. As shown in Figure 10, sensing unit 90 consists of a mounting bracket 92 which is affixed to the scanner housing as shown in Figure 9. Two arms 94 and 96 extend from the bracket 92 and lie on either side of flag 80. An LED device 98 is mounted on arm 94 and a photodiode 100 is mounted on arm 96.

In operation, when mirror 30 rotates through an angle which exceeds approximately 70% of the maximum normal operating angle, light emitted from LED 98 is sensed by photodiode 100 which thereupon gen-

erates an electrical signal. When the angle of rotation of mirror 30 is less than approximately 70% of the maximum normal operating angle, flag 80 is interposed between LED 98 and photodiode 100, in turn, preventing light emitted from LED 98 from reaching diode 100. The signal emitted from diode 100 thereupon ceases. Consequently, as mirror 30 and weight 40 oscillate, an oscillating electrical signal is developed by photodiode 100. This oscillating signal is used to control the driving electronics which provide the current to the coil 66 of the electromagnetic driving motor.

A schematic block diagram of the driving circuit electronics is shown in Figure 11. The basic components of the circuit consists of a comparator 102, a phase-locked loop 104, an automatic gain control circuit 106 and a power amplifier 108. The components are arranged in a conventional frequency control loop. More particularly, the oscillating output signal developed by photodiode 100 is provided to one input of comparator 102. Comparator 102 compares the voltage signal level to a reference voltage in order to standardize the waveform and sharpen the zero crossing points. The output of the comparator is a pulse-train signal which is used to drive the remainder of the circuitry.

The output from comparator 102 is provided to a conventional phase-locked loop circuit 104 which is adjusted to maintain the frequency of oscillation at the desired value. The operation of such a phase-locked loop is conventional and will not be explained hereinafter in detail. Circuit 104 generates control signals which control the power amplifier.

The output of comparator 102 is also provided to a conventional automatic gain control circuit 106 which generates a magnitude control signal.

The control signals generated by phase-locked loop circuit 104 and AGC circuit 106 are provided to power amplifier which provides the driving current to the voice coil and completes the feedback loop.

Figure 12 of the drawing shows an illustrative embodiment of the resonant scanning unit incorporated into a miniature display device. The miniature display device is of the type described in detail in aforementioned patent application EP-A-0 301 801. The operation and construction of the display device is discussed in detail in that application which is hereby incorporated by reference, and will not be repeated in detail herein for clarity. The display device consists of a base 10 on which the various optical components which comprise the display are mounted. At one end of base 10 is mounted the header block 5 in which an array of light-emitting devices 15 (such as light-emitting diodes) is attached. Generally, such an array may be a linear array comprising two rows of devices which are staggered in order to compensate for gaps between the devices. The devices are covered by a clear cover plate 17.

Light emitted from devices 15 is projected on mirror 30 by means of an optical system which consists of housing 18 in which are mounted lenses 19 and 23. In accordance with the principles set forth in the aforementioned patent application EP-A-0 301 801 the lens system projects the image of array 15 via mirror 30.

Mirror 30 is actuated by providing a periodic current via leads 50 and 55 (shown in Figure 4) to coil 46, causing mirror 30 and weight 40 to oscilate. The oscillation of mirror 30, in turn, creates a raster image from linear array 15.

Having thus described one preferred embodiment of the present invention it will be apparent to those skilled in the art that various modifications and alterations are possible without departing from the scope of the invention. For example, instead of the pair of flexure springs used to support the mirror assembly, other conventional arrangements such as four-bar linkages (in which each end of the mirror is attached to the base by means of a separate link) may be used without departing from the scope of the invention. Similarly, a different geometrical arrangement can be used in which the mirror is attached to the base at the center rather than at one end. The invention is not intended to be limited to the preferred embodiment disclosed above. It is limited in scope by the following claims.

Claims

1. A resonant vibrating light deflecting unit, comprising a mounting base (20,21), a first vibrating structure (36) supporting a scanning mirror (30) and resiliently mounted to the mounting base (20,21), and a driving motor means (44,46), **characterised in that** there is a second vibrating structure (40) resiliently mounted to the mounting base (20,21), the driving motor means (44,46) is arranged to oppositely vibrate the vibrating structures (36,40), and the masses of the vibrating structures (36,40) and the resilience with which each is mounted to the mounting base (20,21) are such that the reaction forces in the mounting base (20,21), caused by the operational vibrations of the vibrating structures (36,40), substantially cancel each other.

2. A unit according to claim 1, wherein the driving motor (44,46) is arranged to drive the first (36) and second (40) vibrating structures with a sinusoidal driving force.

3. A unit according to claim 1 or 2, wherein the first vibrating structure (36) is connected to the mounting base (20,21) by means of a first flexure spring (32) and the second vibrating member (40)

is connected to the mounting base (20,21) by means of a second flexure spring (42).

4. A unit according to claim 3, wherein the first and second flexure springs (32,42) are flat flexure springs.

5. A unit according to claim 4, wherein the first vibrating structure (36) is connected to the mounting base (20,21) by means of a third flexure spring (34) in addition to the first flexure spring (32) and the first and third flexure springs (32,34) lie in different planes.

6. A unit according to any preceding claim, wherein the driving motor (44,46) comprises a voice coil (46) mounted on the first vibrating structure (36) and a permanent magnet (44) mounted on the second vibrating structure (40).

7. A unit according to claim 6, wherein the first vibrating structure (36) is connected to the mounting base (20,21) by means of a first electrically-conductive flexure spring (32) and a third electrically-conductive flexure spring (34) and the voice coil (46) is electrically connected (50,55) to the first flexure spring (32) and the third flexure spring (34).

8. A unit according to claim 6, wherein the driving motor (44,46) comprises a drive current circuit (100,102,104,106,108) which supplies a periodic drive current to the voice coil (46).

9. A unit according to claim 8, wherein the periodic drive current is sinusoidal.

10. A unit according to claim 8, wherein the periodic drive current is a square wave current.

11. A method of reducing vibrations of a resonant vibrating light deflecting unit having a mounting base (20,21), a first vibrating structure (36) supporting a scanning mirror (30) and resiliently mounted to the mounting base (20,21), a second vibrating structure (40) resiliently mounted to the mounting base (20,21), and a driving motor means (44,46) arranged to oppositely vibrate the vibrating structures, the method comprising the steps of:
a) resiliently connecting the first vibrating structure (36) to the base (20,21) at a first point (33);
b) resiliently connecting the second vibrating structure (40) to the base at a second point (45), the second vibrating structure being selected so that the mechanical resonant frequency of the mirror (30) and the first vibrating structure (36) is substantially equal to the mechanical resonant frequency of the second vibrating structure (40); and
d) positioning the first point (33) relative to the second point (45) so that the first reaction force substantially cancels the second reaction force at the base (20,21).

12. A method according to claim 11, further comprising the step of controlling the driving motor means (44,46) to drive both vibrating structures (36,40) with a periodic driving force.

13. A method according to claim 12, wherein the periodic driving force is a sinusoidal driving force.

14. A method according to claim 12, wherein the periodic driving force is a square wave driving force.

Patentansprüche

1. Resonanzschwingungs-Lichtablenkeinheit, umfassend eine Grundplatte (20, 21), eine erste Schwingkonstruktion (36), welche einen Abtastspiegel (30) trägt und federnd auf der Grundplatte (20, 21) befestigt ist, sowie ein Antriebsmotormittel (44, 46), dadurch gekennzeichnet, daß eine zweite Schwingkonstruktion (40) federnd auf der Grundplatte (20, 21) befestigt ist, das Antriebsmotormittel (44, 46) angeordnet ist, um die Schwingkonstruktionen (36, 40) entgegengesetzt in Schwingungen zu versetzen, und die Massen der Schwingkonstruktionen (36, 40) und die Federung, mit welcher jede davon auf der Grundplatte (20, 21) befestigt ist, derart sind, daß die Reaktionskräfte in der Grundplatte (20, 21), welche durch die Betriebsschwingungen der Schwingkonstruktionen (36, 40) verursacht werden, einander im wesentlichen aufheben.

2. Einheit nach Anspruch 1, wobei der Antriebsmotor (44, 46) angeordnet ist, um die erste (36) und die zweite (40) Schwingkonstruktion mit einer sinusförmigen Antriebskraft anzutreiben.

3. Einheit nach Anspruch 1 oder 2, wobei die erste Schwingkonstruktion (36) mit der Grundplatte (20, 21) über eine erste Biegefeder (32) verbunden ist und das zweite Schwingglied (40) mit der Grundplatte (20, 21) über eine zweite Biegefeder (42) verbunden ist.

4. Einheit nach Anspruch 3, wobei die erste und die zweite Biegefeder (32, 42) flache Biegefedern sind.

5. Einheit nach Anspruch 4, wobei die erste

Schwingkonstruktion (36) mit der Grundplatte (20, 21) außer über die erste Biegefeder (32) auch noch über eine dritte Biegefeder (34) verbunden ist und die erste und die dritte Biegefeder (32, 34) in verschiedenen Ebenen liegen.

6. Einheit nach einem der vorangehenden Ansprüche, wobei der Antriebsmotor (44, 46) eine Schwingspule (46), welche auf der ersten Schwingkonstruktion (36) befestigt ist, und einen Permanentmagneten (44) umfaßt, welcher auf der zweiten Schwingkonstruktion (40) befestigt ist.

7. Einheit nach Anspruch 6, wobei die erste Schwingkonstruktion (36) mit der Grundplatte (20, 21) über eine erste elektrisch leitende Biegefeder (32) und eine dritte elektrisch leitende Biegefeder (34) verbunden ist und die Schwingspule (46) an die erste Biegefeder (32) und die dritte Biegefeder (34) elektrisch angeschlossen (50, 55) ist.

8. Einheit nach Anspruch 6, wobei der Antriebsmotor (44, 46) einen Antriebsstromkreis (100, 102, 104, 106, 108) umfaßt, welcher die Schwingspule (46) mit einem periodischen Antriebsstrom versorgt.

9. Einheit nach Anspruch 8, wobei der periodische Antriebsstrom sinusförmig ist.

10. Einheit nach Anspruch 8, wobei der periodische Antriebsstrom ein Rechteckwellenstrom ist.

11. Verfahren zum Reduzieren der Schwingungen einer Resonanzschwingungs-Lichtablenkeinheit, umfassend eine Grundplatte (20, 21), eine erste Schwingkonstruktion (36), welche einen Abtastspiegel (30) trägt und federnd auf der Grundplatte (20, 21) befestigt ist, eine zweite Schwingkonstruktion (40), welche federnd auf der Grundplatte (20, 21) befestigt ist, sowie ein Antriebsmotormittel (44, 46), welches angeordnet ist, um die Schwingkonstruktionen entgegengesetzt in Schwingungen zu versetzen, wobei das Verfahren die folgenden Schritte umfaßt:

a) das federnde Verbinden der ersten Schwingkonstruktion (36) mit der Grundplatte (20, 21) an einem ersten Punkt (33);

b) das federnde Verbinden der zweiten Schwingkonstruktion (40) mit der Grundplatte an einem zweiten Punkt (45), wobei die zweite Schwingkonstruktion derart gewählt wird, daß die mechanische Eigenfrequenz des Spiegels (30) und der ersten Schwingkonstruktion (36) im wesentlichen gleich der mechanischen Eigenfrequenz der zweiten Schwingkonstruktion (40) ist; und

d) das Anordnen des ersten Punktes (33) in bezug auf den zweiten Punkt (45), so daß die erste Reaktionskraft die zweite Reaktionskraft an der Grundplatte (20, 21) im wesentlichen aufhebt.

12. Verfahren nach Anspruch 11, des weiteren umfassend den Schritt des Regelns des Antriebsmotormittels (44, 46), um beide Schwingkonstruktionen (36, 40) mit einer periodischen Antriebskraft anzutreiben.

13. Verfahren nach Anspruch 12, wobei die periodische Antriebskraft eine sinusförmige Antriebskraft ist.

14. Verfahren nach Anspruch 12, wobei die periodische Antriebskraft eine Rechteckwellen-Antriebskraft ist.

Revendications

1. Unité de déflexion de lumière à résonance vibratoire, comprenant une base de montage (20, 21), une première structure vibrante (36) supportant un miroir de balayage (30) et montée élastiquement sur cette base de montage (20, 21), et des moyens d'entraînement par moteur (44, 46),

caractérisée en ce qu'elle comprend une seconde structure vibrante (40), montée élastiquement sur la base de montage (20, 21), les moyens d'entraînement par moteur (44, 46) étant prévus pour provoquer la vibration en opposition des structures vibrantes (36, 40), et les masses des structures vibrantes (36, 40) et l'élasticité avec laquelle chacune est montée sur la base de montage (20, 21) sont telles que les forces de réaction dans la base de montage (20, 21) provoquées par les vibrations opératoires des structures vibrantes (36, 40) s'annulent pratiquement l'une l'autre.

2. Unité selon la revendication 1, dans laquelle les moyens d'entraînement motorisés (44, 46) sont agencés de manière à entraîner la première structure vibrante (36) et la seconde structure vibrante (40) avec une force d'entraînement sinusoïdale.

3. Unité selon la revendication 1 ou 2, dans laquelle la première structure vibrante (36) est fixée sur la base de montage (20, 21) au moyen d'un premier ressort de flexion (32) et le second élément vibrant (40) est fixé sur la base de montage (20, 21) au moyen d'un second ressort de flexion (42).

4. Unité selon la revendication 3, dans laquelle le premier et le second ressort de flexion (32, 42) sont des ressorts à lame de flexion plate.

5. Unité selon la revendication 4, dans laquelle la première structure vibrante (36) est fixée à la base de montage (20, 21) au moyen d'un troisième ressort de flexion (34), en plus du premier ressort de flexion (32), et le premier et le troisième ressort de flexion (32, 34) sont situés dans des plans différents.

6. Unité selon l'une quelconque des revendications précédentes, dans laquelle le moteur d'entraînement (44, 46) comprend un enroulement vocal (46) monté sur la première structure vibrante (36) et un aimant permanent (44) monté sur la seconde structure vibrante (40).

7. Unité selon la revendication 6, dans laquelle la première structure vibrante (36) est fixée à la base de montage (20, 21) au moyen d'un premier ressort de flexion (32) électriquement conducteur et d'un troisième ressort de flexion (34) électriquement conducteur, et l'enroulement vocal (46) possède des liaisons électriques (50, 55) avec le premier ressort de flexion (32) et le troisième ressort de flexion (34).

8. Unité selon la revendication 6, dans laquelle le moteur d'entraînement (44, 46) comporte un circuit de courant d'alimentation (100, 102, 104, 106, 108) fournissant un courant d'alimentation périodique à l'enroulement vocal (46).

9. Unité selon la revendication 8, dans laquelle le courant d'alimentation périodique est sinusoïdal.

10. Unité selon la revendication 8, dans laquelle le courant d'alimentation périodique est à ondes carrées.

11. Méthode de réduction des vibrations d'une unité de déflexion de lumière à résonance vibratoire, ayant une base de montage (20, 21), une première structure vibrante (36) supportant un miroir de balayage (30) et montée élastiquement sur la base de montage (20, 21), une seconde structure vibratoire (40) montée élastiquement sur la base de montage (20, 21) et des moyens d'entraînement motorisés (44, 46) agencés de manière à faire vibrer en opposition les structures vibrantes, cette méthode comprenant comme étapes :

a) fixer élastiquement la première structure vibrante (36) à la base (20, 21) en un premier point (33) ;

b) fixer élastiquement la seconde structure vibrante (40) à la base en un second point (45), la seconde structure vibrante étant sélectionnée de manière telle que la fréquence de résonance mécanique du miroir (30) et de la première structure vibrante (36) est pratiquement égale à la fréquence de résonance mécanique de la seconde structure vibrante (40) ; et

c) positionner le premier point (33) par rapport au second point (45) de manière telle que la première force de réaction annule pratiquement la seconde force de réaction vis à vis de la base (20, 21).

12. Méthode selon la revendication 11, comprenant au surplus l'étape consistant à contrôler les moyens d'entraînement motorisés (44, 46) de manière à entraîner les deux structures vibrantes (36, 40) avec une force d'entraînement périodique.

13. Méthode selon la revendication 12, dans laquelle la force d'entraînement périodique est une force d'entraînement sinusoïdale.

14. Méthode selon la revendication 12, dans laquelle la force d'entraînement périodique est une force d'entraînement à ondes carrées.

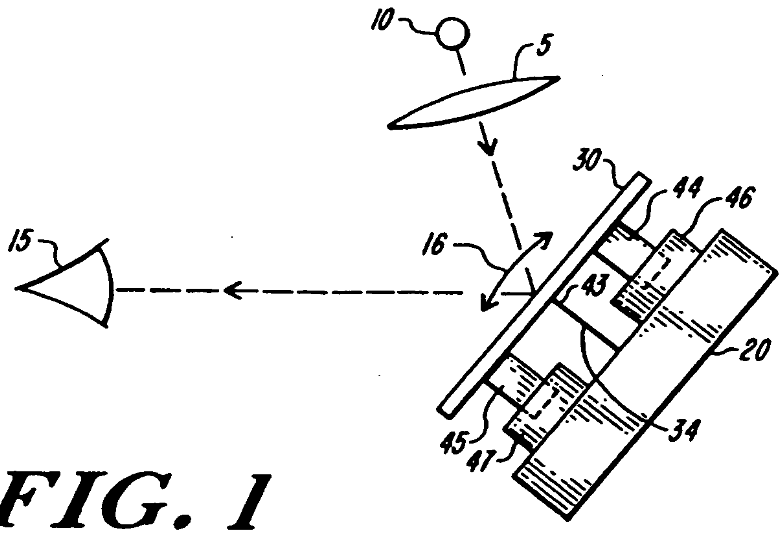

FIG. 1
(PRIOR ART)

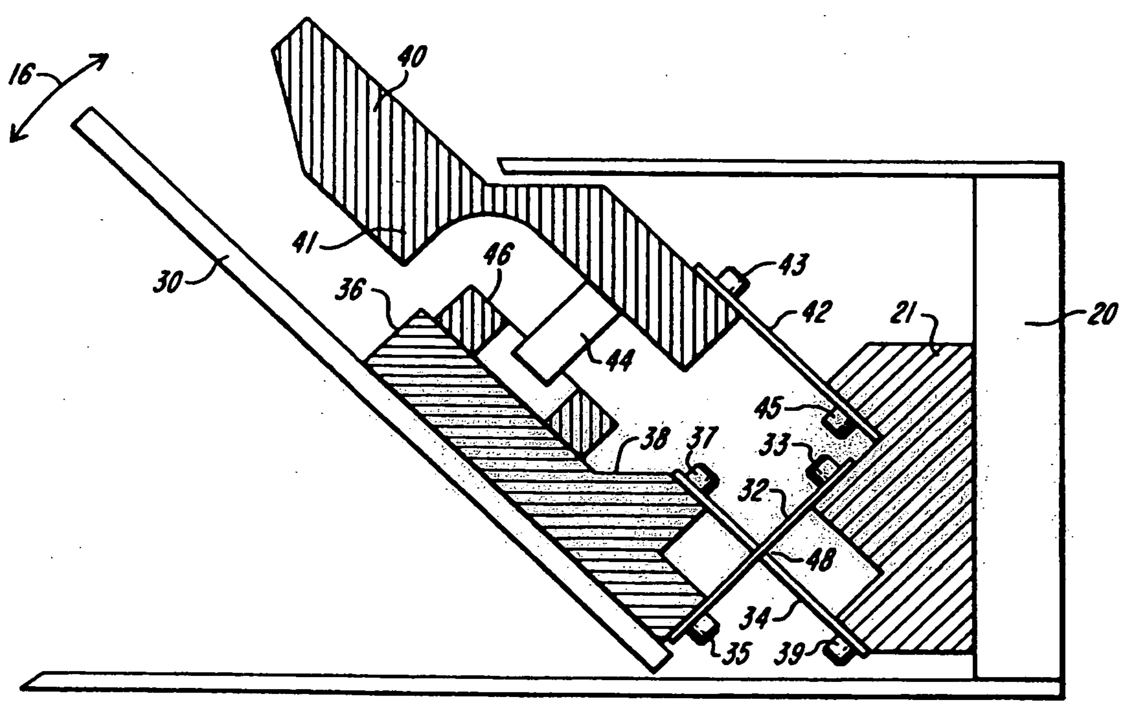

FIG. 2

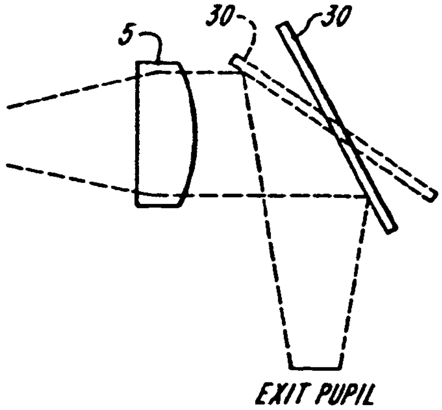

FIG. 3A

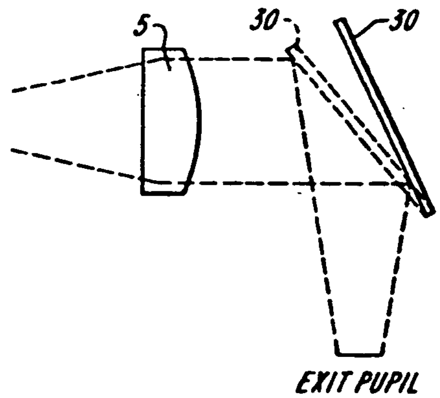

FIG. 3B

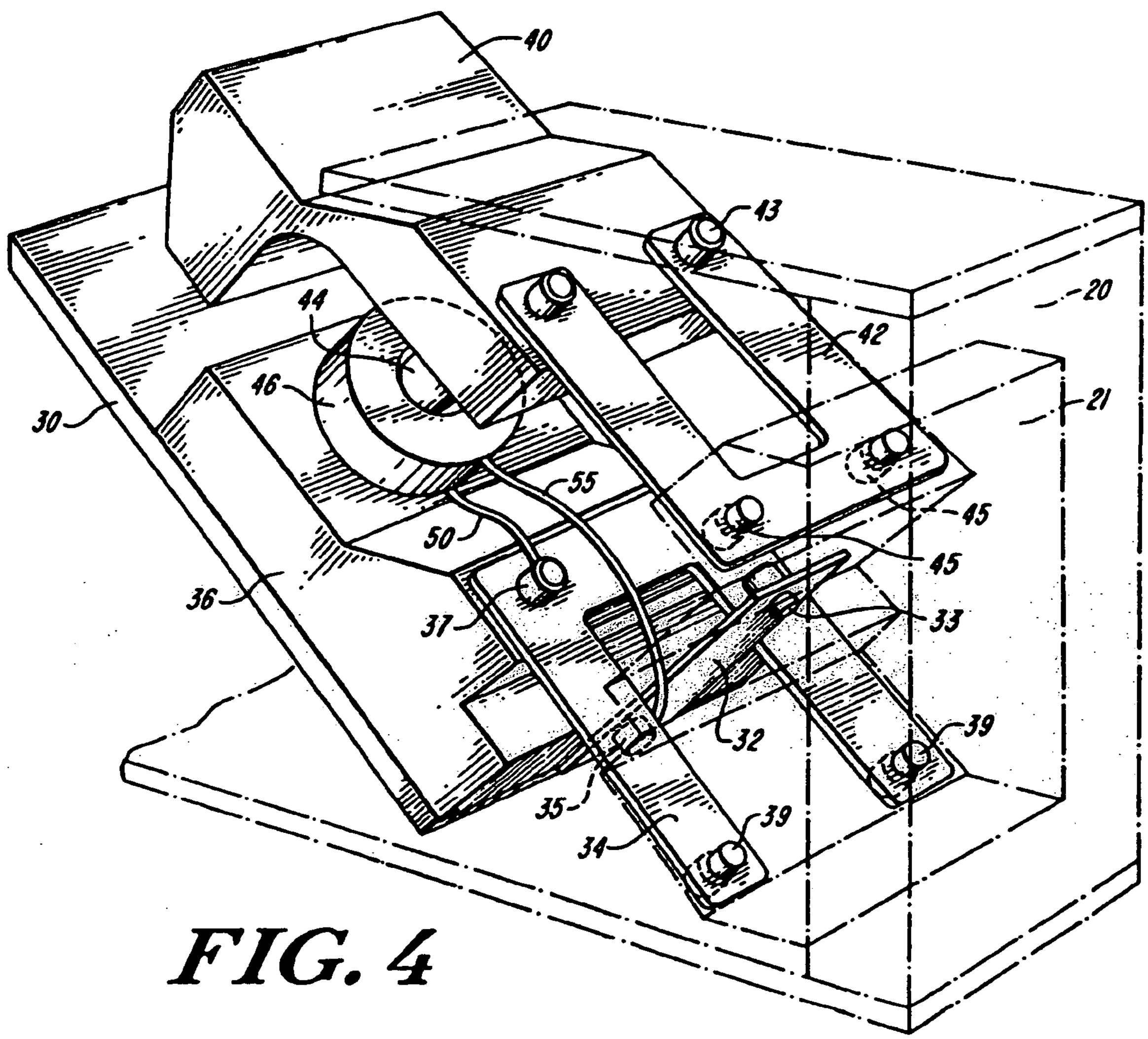

FIG. 4

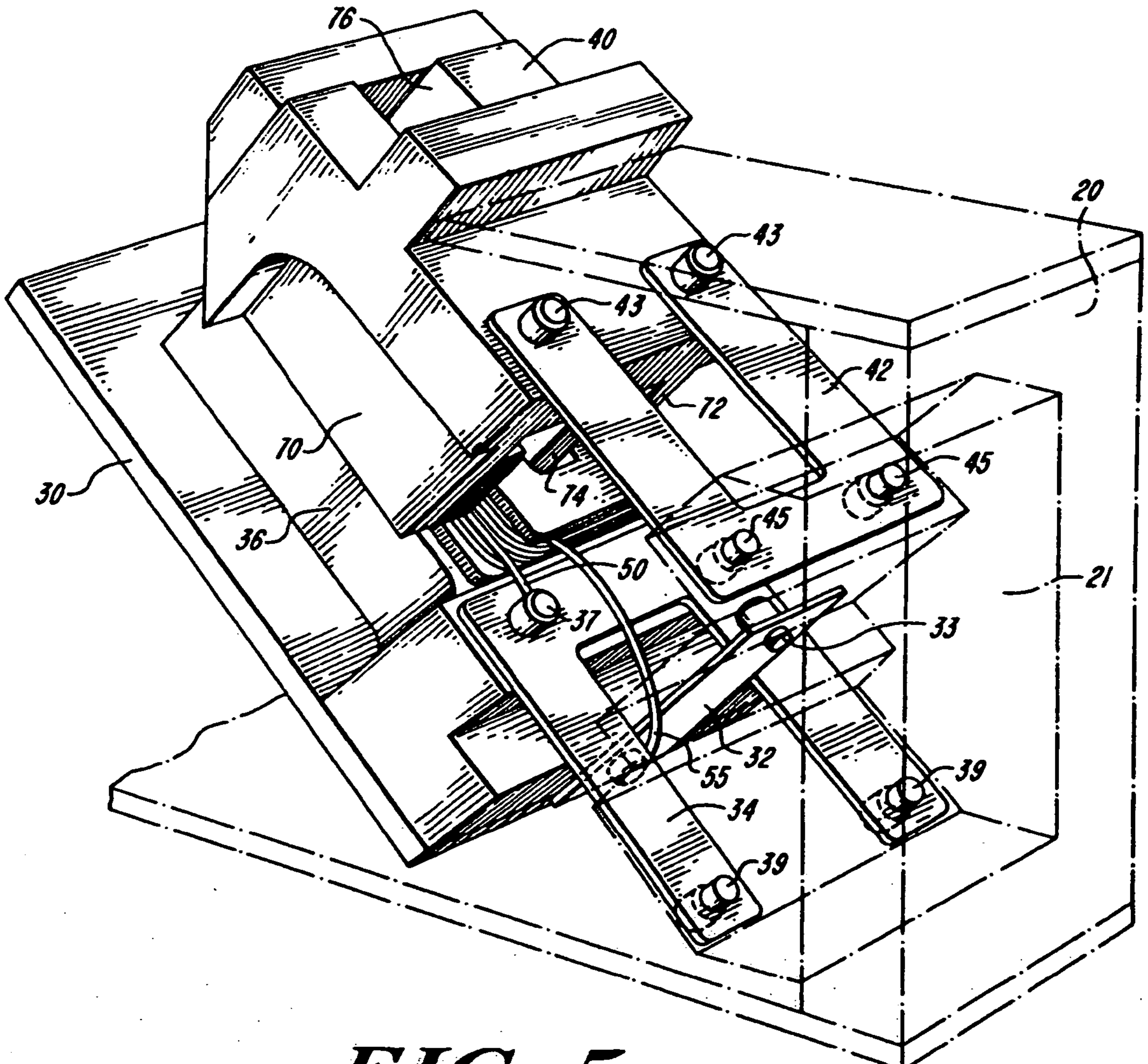

FIG. 5

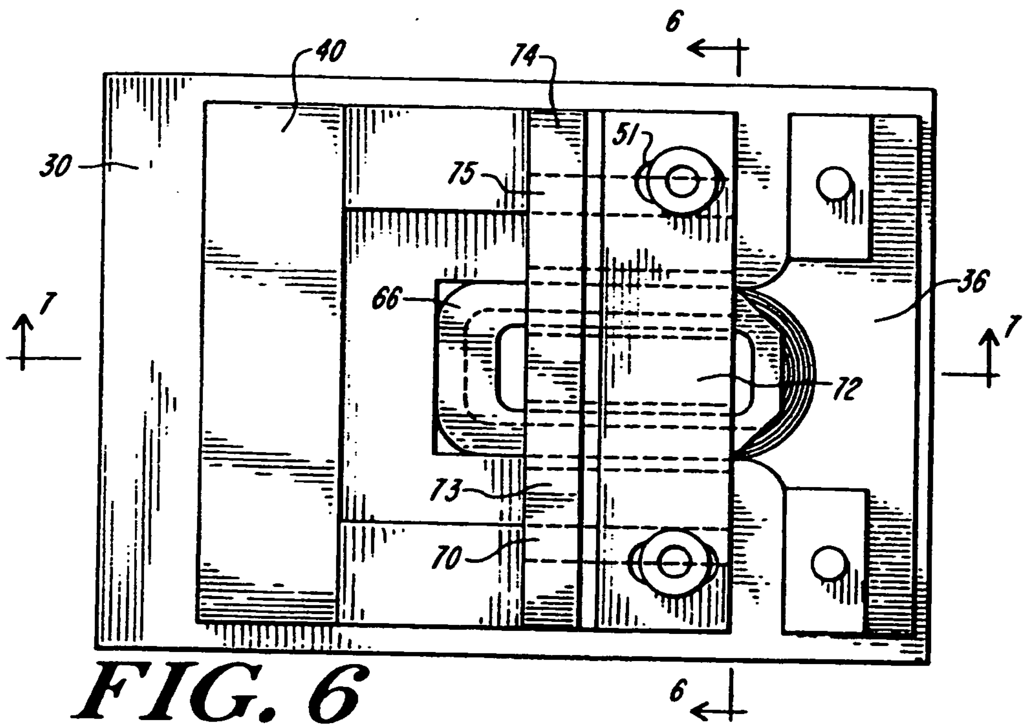

FIG. 6

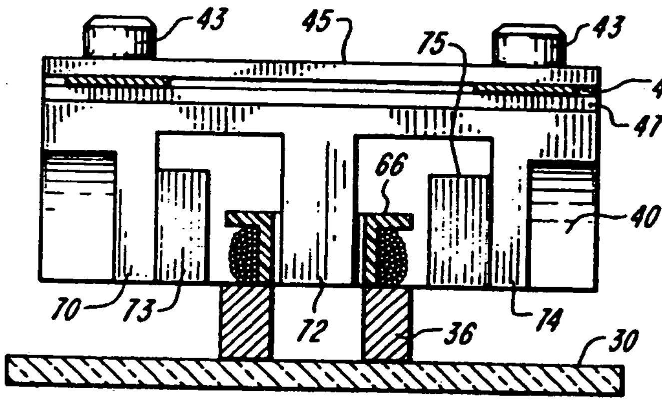

FIG. 7

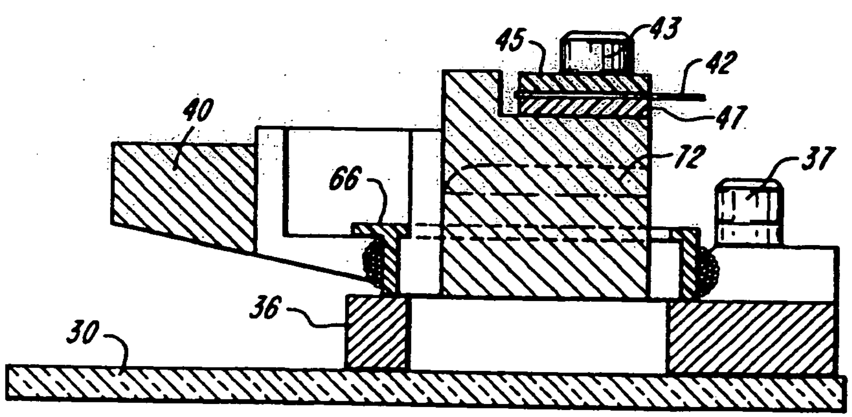

FIG. 8

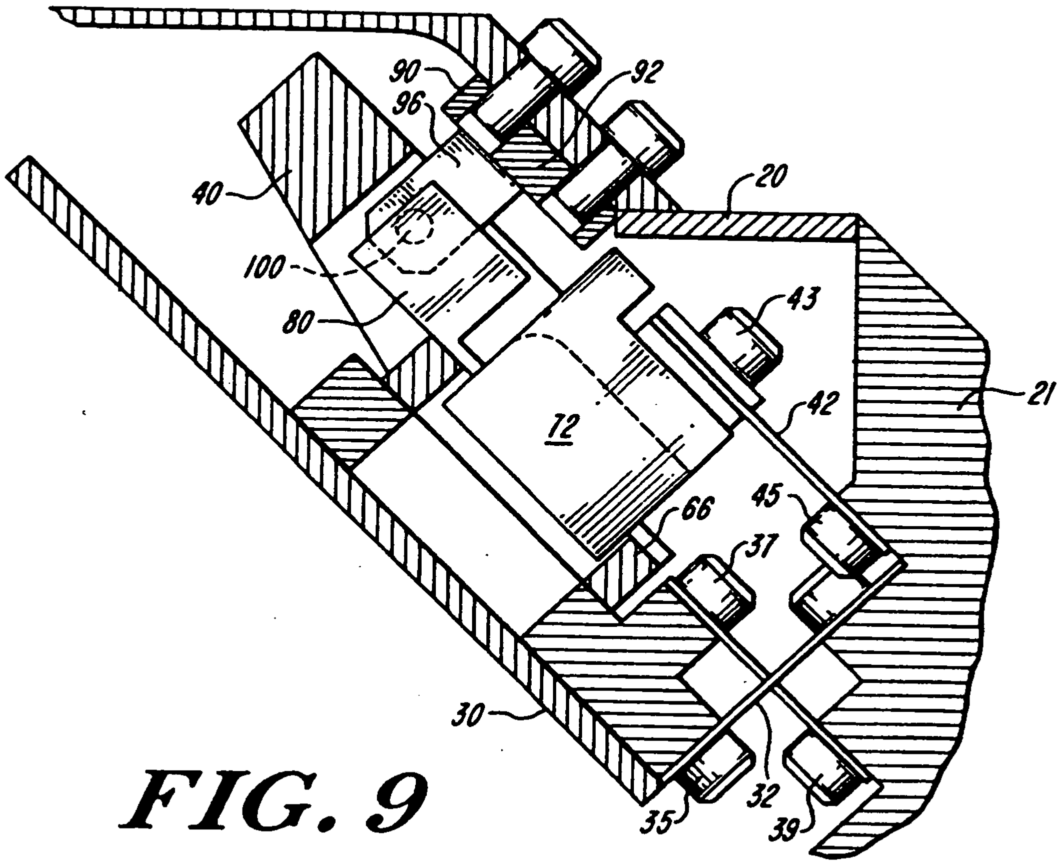
90
92
96
20
40
100
43
80
21
42
72
45
66
37
30
32
35
39

FIG. 9

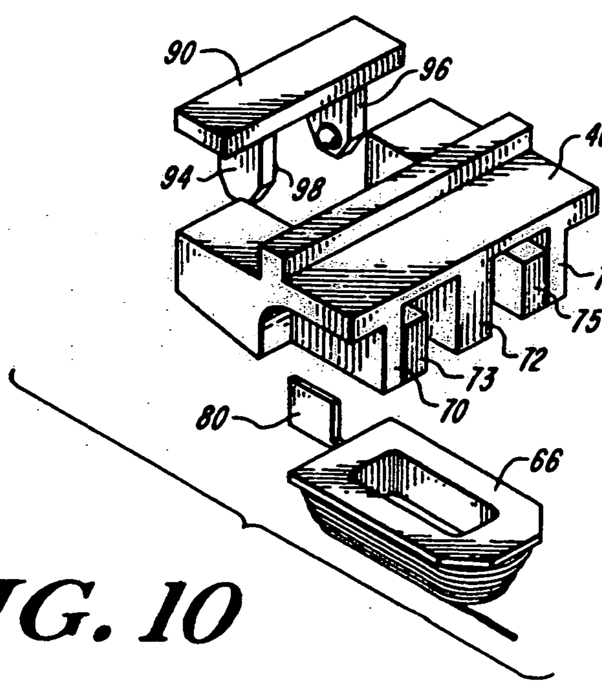
90
96
40
94
98
74
75
72
73
70
80
66

FIG. 10

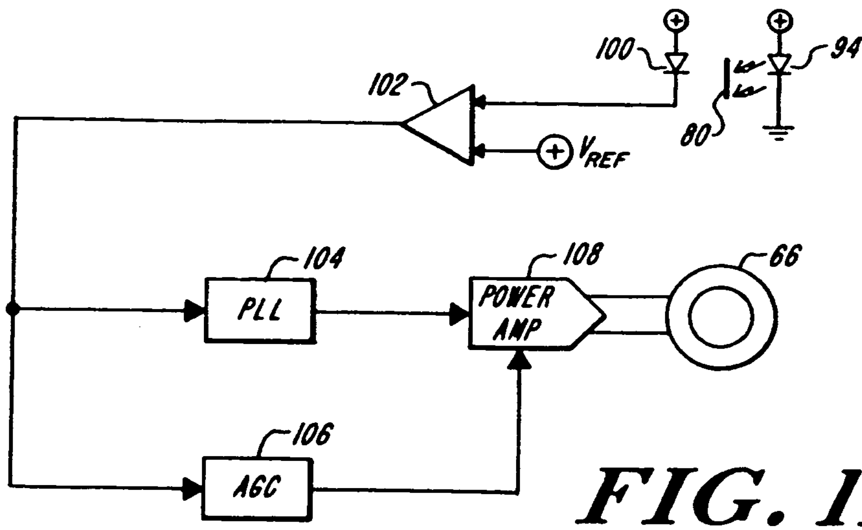
100
94
102
80
V_{REF}
104
108
66
PLL
POWER AMP
106
AGC

FIG. 11

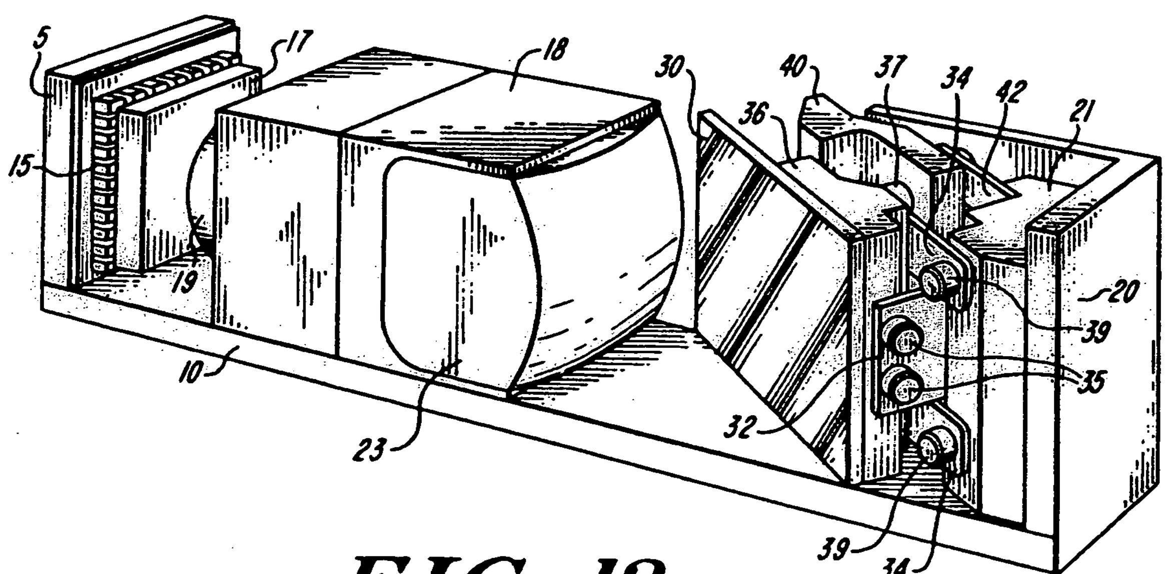
5
17
18
30
40
37
34
42
21
36
15
19
20
39
35
10
32
23
39
34

FIG. 12